INSTITUTO SUPERIOR TÉCNICO
Universidade Técnica de Lisboa

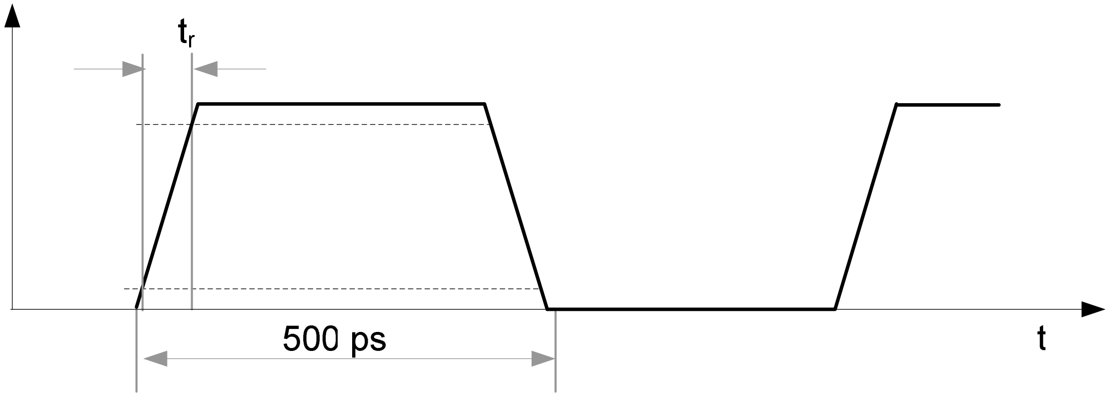
Interconnections

Outline

- The importance of interconnect design
- The basics of digital design
- Brief history of digital design
- Interconnecting: cables, connectors, packages, PCB traces and ICs
- Emerging technologies

The importance of interconnect design

- Commonplace, modern, volume-manufactured digital systems require control of timings down to the picosecond range. Operating up to gigahertz frequencies, rise times can be in the order of fifty picoseconds.



F = 1 GHz
duty cycle 50%

tr = 10% of T/2 = 50 ps

- This level of timing must be maintained at the silicon level, at PCB board (ex: computer motherboard) and at system level (cables, connectors).

The importance of interconnect design

- The main problem is not the clock period (or frequency), but the rise (and fall) time. However, systems with faster clock frequency usually have shorter rise time.
- It is the rise (and fall) time that are responsible by the highest frequency in the spectrum (Fourier analysis) of the signal carried by the interconnection.
- When the length of the conductor (wire) approaches the order of magnitude of the wave length (about 1/10 of the wave length) the conductor behaves as a transmission line. When this occurs, circuit analysis rules don't apply anymore.

For a rise time of 50 ps light travels 1.5 cm.

On a PCB (about half the speed of the light) 50 ps occupies 0.75 cm on a circuit trace.

The importance of interconnect design

- Conductor capacitance, inductance and resistance depend on the frequency. At high frequencies, none of them are negligible.
- The conductor is coupled to everything around it: power, ground and other conductors. Signals are affected by other signals. Complex interactions will occur between different parts of the same interconnect: packages, connectors, bias and bends.
- Conductors must be handled carefully to avoid timing problems in circuits and systems.

The importance of interconnect design

- Conductor capacitance, inductance and resistance depend on the frequency. At high frequencies, none of them are negligible.
- The conductor is coupled to everything around it: power, ground and other conductors. Signals are affected by other signals. Complex interactions will occur between different parts of the same interconnect: packages, connectors, bias and bends.
- Conductors must be handled carefully to avoid timing problems in circuits and systems.
- At high frequencies, concepts already used, for several decades, in radio frequency and microwave design apply. Digital design acquires the complexity of the analog design.

- **Both analog and digital design need to use techniques for high frequency.**

The importance of interconnect design

- High-speed effects tend to produce strange distorted waveforms that will give a complete different view of logic signals. There are a large number of codependent effects that affect the outcome of the signal.
- It is very difficult to handle so many variables, whether they are controllable or uncontrollable.
- **This is not black magic**. It is a matter of knowing which principles apply to minimize the uncertainty, even though a certain amount of guesswork is always present in a design.

The basics of digital design

- Basic idea in digital design: communication of information with signals representing 1s (high voltage) and 0s (low voltage)

- Under all conditions:
  - High voltages ≥ V_{IH}
  - High voltages ≤ V_{IL}

- Rise and fall times must be as fast as possible to maximize speed of operation: few hundred picoseconds can be encountered.

- Interconnections have a vital role of guaranteeing proper signals transitions through V_{IH} and V_{IL} with the appropriate timing.

Brief history

80’s: Increase in VLSI digital design

- Advances in IC process technology favoured mainly digital circuits
- Functions (filter, signal processors, etc) traditionally realised in analog form were easily performed in the digital domain

90’s: Increase in clock frequencies (Moore´s law)

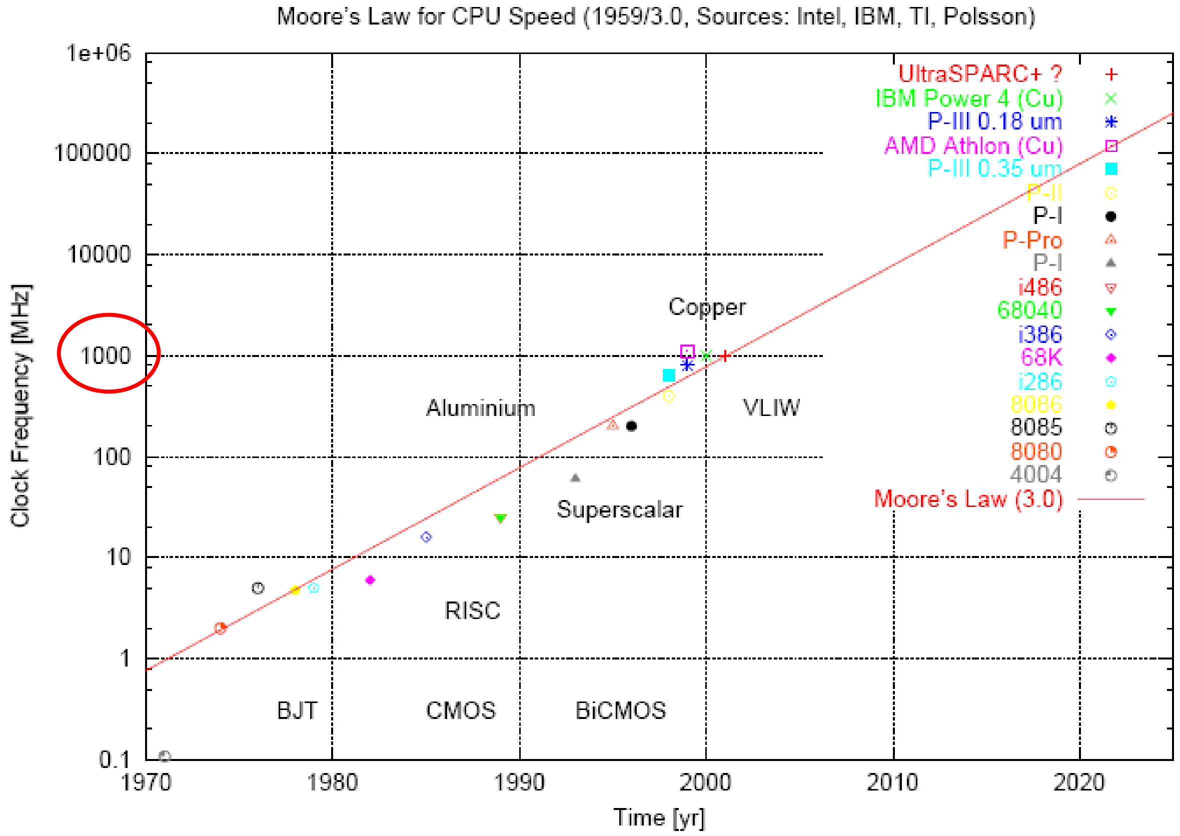
- Faster data rates demanded from the buses → decrease of interconnect timing

2000’s:

- **High-speed design, in fact analog design**

Brief history

Moore´s Law for computer performance (internal clock rate)



Interconnecting: cables, ….

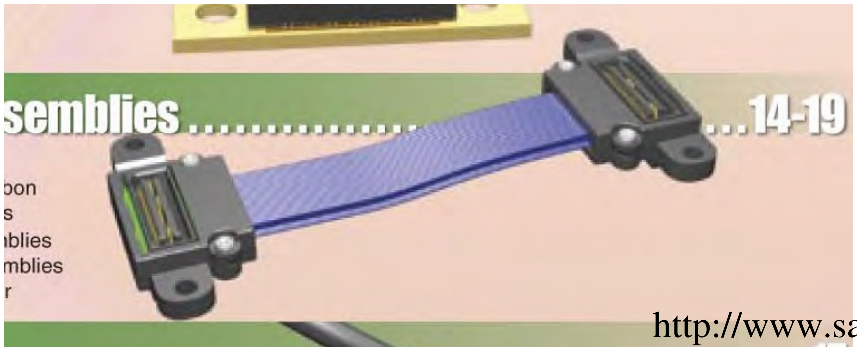
The pieces of the interconnection puzzle include:

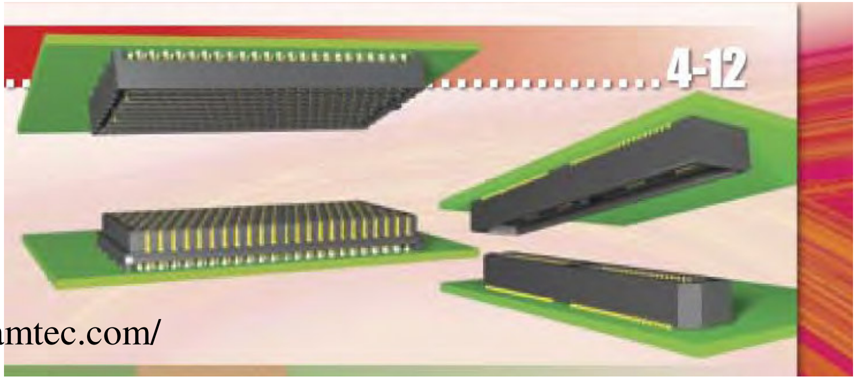
- cables
- connectors
- PCBs
- IC packages
- System-on-Chip (SoC)

scaling down

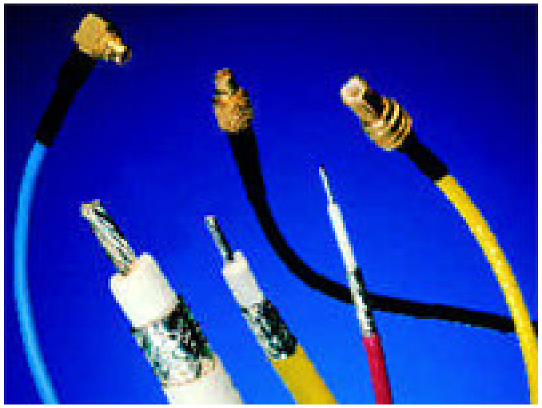
Interconnecting: cables, ….

- Cables, connectors

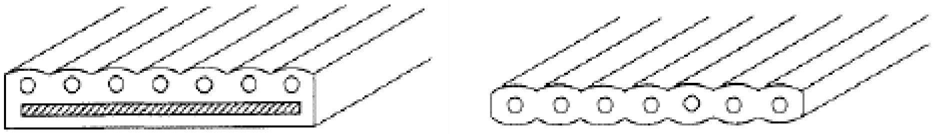




http://www.samtec.com/



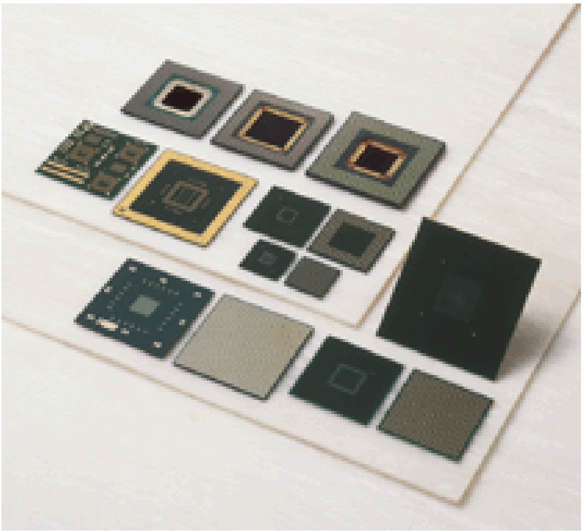
http://www.gore.com/



Interconnecting: cables, ….

- Packages

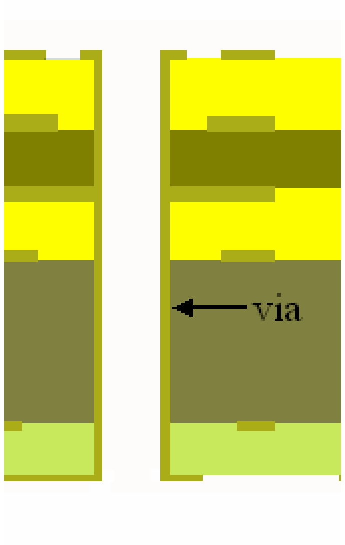
http://solutions.3m.com/



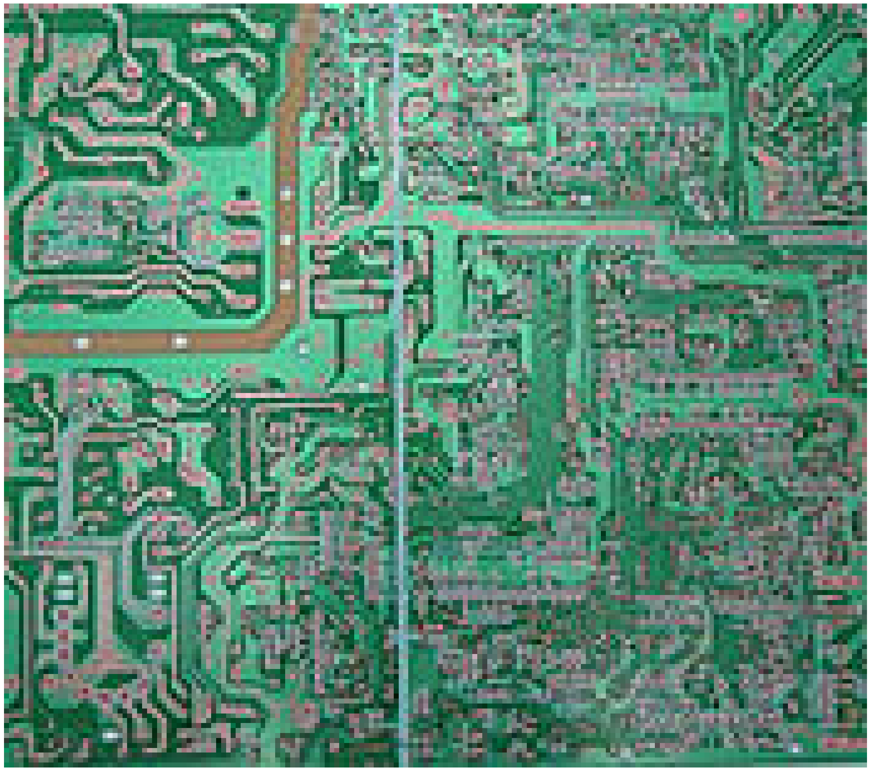
http://global.kyocera.com/

Interconnecting: cables, ….

- PCB traces and vias



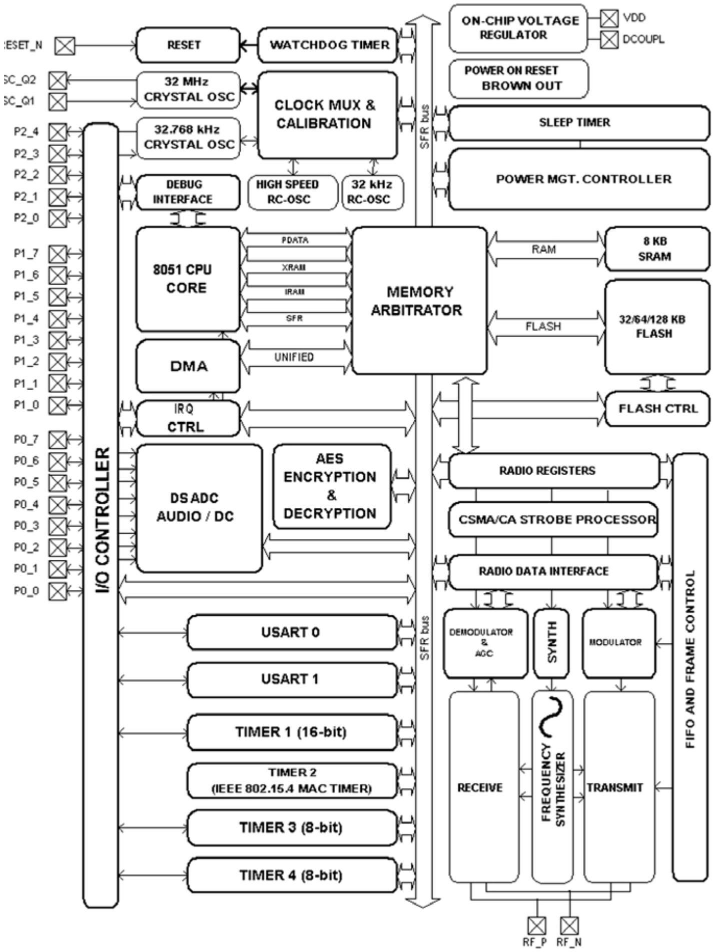
FR4 -multilayer



http://www.clarydon.com

Interconnecting: cables, ….

- SoCs



Low-Power RF System-on-Chip for ZigBee
www.ti.com

Emerging technologies

ASICs and FPGAs, now including LVDS I/O options

- LVDS- Low Voltage Differential Voltage (TIA/ EIA-644)
  - balanced differential pair
  - swing of only 345 mV
  - can have signal transition time as short as 260 ps turning a printed circuit board trace into a transmission line in a few centimeters.
- M-LVDS: A New Standard for High-Speed Multipoint Data Buses